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THE INHERITANCE OF RED COLOUR, AND THE REGULARITY OF SELF-FERTILISATION, IN *CORCHORUS CAPSULARIS, LINN.*, THE COMMON JUTE PLANT

BY

R. S. FINLOW, B.SC., F.C.S

Fibre Expert to the Government of Eastern Bengal and Assam

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Economic Botanist to the Botanical Survey of India

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FROM 1902 to 1907 we were engaged in making a preliminary survey of the races of jute cultivated in India, and, in the Agricultural Ledger No. 6 of 1907, we gave an account of our results to that date. We had under observation, from year to year, during this investigation, plots representing practically all* the races recognized by the ryots in every part of the two Bengals. These plots were both on the Burdwan Experimental Farm and at the Pusa Research Institute; and in several years they were over one hundred in number. Red races and green ones stood side by side: but the races seemed to reproduce true, after we had weeded out from them the aberrant plants, which sprang from the original, and often very impure, seed which we obtained from the districts.

As a result of our preliminary survey we kept apart thirty-three races of *Corchorus capsularis*, including three grown only

* A new variety, *C. capsularis*, var. *ovocarpus*, was discovered by us in 1910 (Jour. Asiatic Society, Bengal, N. S. VII, 1911, p. 465); but no new races of true *C. capsularis* have since been met with.

to serve as a vegetable. The races may be grouped conveniently under the following colour types :—

(*a*) deep red stem, petioles and fruits, with the teeth of the leaves also tipped with red ;

(*b*) brownish red stems, petioles and fruits, with no distinct red borders to the leaves ;

(*c*) green stems with reddish petioles and fruits ;

(*d*) pure green stems, petioles and fruits.

The tints of the various red races contained in group (*a*) or group (*b*) were not, of course, exactly identical ; the members of the groups (*a*), (*b*), and (*c*) rather formed a series of colour gradations between the extreme types—pure red and pure green.

The red colour is a soluble pigment, turning brilliant malachite green with alkali and bright carmine with acid,* found—

(*i*) chiefly in the brick-shaped parenchyma cells, which lie immediately under the epidermis of the stems and petioles ;

(*ii*) in the parenchyma of the petioles, sporadically, even as deep as the phloem ;

(*iii*) in sub-epidermal cells near the margin of the leaf and

(*iv*) in small multicellular hairs on the leaf and on the stipules.

The intensity of the colour of a red-stemmed jute is due to an almost general distribution of the pigment in the sub-epidermal cells of the parts coloured. Conversely, the fewer the pigmented cells the less red the stem ; until, in pure green races, they are absent. Even the stems of members of class (*c*) (green stems with red petioles) shew, under the microscope, a few red cells. There are therefore only two real colour types in jute, capable of exact, ready definition, *viz.* :—red and green ; and the classes (*a*), (*b*) and (*c*) in the colour scheme given above, are convenient but arbitrary divisions of degree in colour, without definite boundary lines.

When a jute seedling appears above ground, whether it be of a red or of a green stemmed race, it is, to the eye, wholly

* A pure green plant—one which, under the microscope, shows no red cells at all—does not give this colour reaction.

green; though, under a microscope, a few red cells may be detected, in a red race, at the points where the blade and petiole of the cotyledons join. The pigment becomes obvious, later, when it diffuses over the surface of the epicotyl and is visible, if the race be a red one, on the petiole and on the margin of the first leaf after the cotyledons. Succeeding leaves show still more red; and the epicotyl, stem, and petioles grow redder. This change we shall illustrate by two counts made of the progeny of plants 119 and 214 (what these plants were will be obvious later): the plants counted were a mixed series grown in two lines: they were examined carefully when a fortnight old and classed into "red stemmed," "pale red stemmed," "green stemmed with red petioles" and "pure green": they were examined again and reclassed when a month old. In the meantime a few belated seeds had germinated, altering the total slightly.

	Red.	Pale red.	Red petioled.	Green.
1st counting ...	148	440	250	253
Later counting ..	250	493	109	259

The figures suggest that approximately 102 plants, classed as pale red stemmed at the first counting, had become distinctly red at the later counting; 155 plants classed as having only red petioles at the first counting had become pale red at the later counting, and 14 more plants had been added to the red series, either from those considered to be green at the first count; or, from the 20 new germinations.

The lesson learned from this is that, in order to determine how many red and how many green plants there may be in a bed, it is necessary to wait until the plants have had time to declare themselves.

In 1906 (*vide* the "Journal of the Asiatic Society of Bengal," N. S. II, pp. 515-519) one of us (I. H. B.) gave an account of the jute flower, showing it to be self-fertile and self-pollinated, but that insect visitors go to it. The structure of the flower is such, we shewed, that, unless foreign pollen is prepotent, self-fertilization is not unlikely to result from an insect visit. It was necessary however to have more positive evidence on this point, when

breeding experiments were commenced ; because, if cross-fertilization under normal circumstances be at all common, special precautions must be taken, to exclude insects from the parent flowers. The results given below are, we think, sufficient evidence that cross-pollination is rare enough to be ordinarily negligible.

Cross-fertilization with pure types of Red and Green Plants.

In 1908 we took two races of *C. capsularis*, that had been under observation long enough for us to be certain that they reproduced pure, *viz.* :—

(1) Desi of Dacca.
(2) Bhadya Red of Jalpaiguri.

The first has no red colour, *i.e.*, it is pure green throughout ; while the second is deep red in stems, petioles and fruits. We cross-fertilized flowers of plants belonging to these races, in both directions, and we selected, from among others obtained in this way, four capsules with good seed, of which, in two cases, a Bhadya plant was the female parent and, in the other two, a plant of Desi.

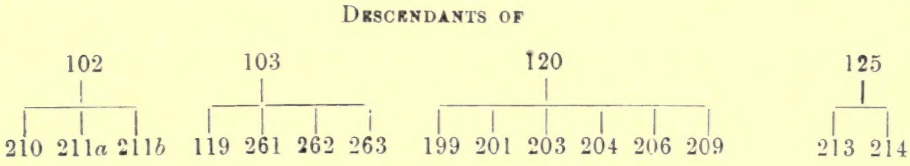
It was found that, at Pusa, the anthers dehisce about sunrise ; so that it was necessary to emasculate the flower of the female parent on the previous evening and to cross it as early as possible the next morning. A bag was tied over the ruptured bud, to protect it during the night ; the bag being retained, after pollination, until the capsule began to swell. As a control, a considerable number of other flowers were also emasculated in the evening, but not pollinated on the next morning. No one of these latter set any seed, while the percentage of successes in the case of the crossed flowers was over fifty. Considerably more than four crossed flowers set seed, but the four plants already mentioned were the only ones with which the experiment was continued. The four capsules were numbered 102, 103, 120 and 125 respectively.

In 1909, the seed from each of these capsules was sown, on the 9th July, in pots in the pot-culture house at Pusa and 15 plants in all were raised to maturity, *viz.* :—

3 from No. 102
4 ,, No. 103
6 ,, No. 120
2 ,, No. 125

All these plants had red colour in their stems ; thus suggesting that red behaves as a dominant characteristic in jute as apparently it has done in most species of plants where red-stemmed and green-stemmed races have been crossed. It was noticed, however, that the red colour in the hybrid progeny was always less intense than in the parent plant, an observation which has been confirmed by more recent experiments.

The plants were numbered as follows :—



Several flowers on each of these plants were carefully self-pollinated and good seed was obtained from all plants, excepting Nos. 199 and 204.

This seed was sown, in lines, on the Dacca Farm on May 18th, 1910. At the same time seed, from the same plants respectively, but produced from flowers left to be fertilized naturally,* was sown in adjacent lines. On germination it was seen that the plants, from both selfed and from ordinarily fertilized flowers, varied in colour from red to pure green. When

* Side by side with the pots in which the hybrids were growing were several pots containing pure green jute plants.

a fortnight old, they were counted and classified into the following :—

(*a*) Red stems with red petioles and fruits.
(*b*) Light red stems, petioles and fruits.
(*c*) Green stem with reddish petioles and fruits.
(*d*) Pure green.

When one month old, the plants were again recounted and reclassified. Three counts were made in all.

Table I gives the numbers of the respective colours, at the last count, of the plants grown from seed produced by self-fertilized flowers, together with the ratio of the number of mixed red plants to those of pure green colour :—

Table No. I.

Proportion of red to green plants in the F_2 generation selfed plants.

	Number of flower in 1908.	Number of flower in 1909.	Number of plants of different Colours. Red stems.	Light red stems.	Green stems with red petioles.	Pure green.	Ratio of red plants all together to pure green plants.
Bhadya ♂ ... × Desi ♀ ...	103	119	9	10	6	11	2·3 : 1
		261	5	12	1	4	4·5 : 1
		262	10	15	3	5	5·6 : 1
		263	6	15	2	9	2·6 : 1
Bhadya ♂ ... × Desi ♀ ...	102	210	51	64	15	42	2·9 : 1
		211*a*	25	55	13	28	3·3 : 1
		211*b*	9	20	7	12	3·0 : 1
Desi ♂ ... × Bhadya ♀ ...	120	201	12	36	6	14	3·9 : 1
		203	8	18	0	6	4·3 : 1
		206	63	106	32	56	3·6 : 1
		209	14	56	9	26	3·0 : 1
Desi ♂ ... × Bhadya ♀ ...	125	213	7	19	6	10	3·2 : 1
		214	31	67	9	36	3·0 : 1
Total ...	.....	...	250	493	109	259	Mean ratio. 3·3 : 1

The table proves that, of the two alternative characters—presence of red colouration and its absence, the first is dominant

and the second recessive, in crosses. Theoretically, the ratio should be 3 to 1, instead of 3·3 to 1 as found.

The seed saved from the selected capsules which had been left to be fertilized naturally gave plants as shown in Table II. The ratio of those with red pigment to those without is almost exactly 3 : 1 in this case.

Table No. II.

Proportion of red to green plants in the F_2 generation, from flowers naturally fertilized.

	Flower number in 1908.	Flower number in 1909.	Red stems.	Pale red stems.	Green stems with red petioles.	Pure green.	Ratio.
Bhadya ♂ × Desi ♀	103	261	47	139	98	96	3·0 : 1
		262	27	78	25	44	3·0 : 1
		263	21	66	16	35	3·0
Bhadya ♂ × Desi ♀	102	210	79	177	177	133	3·3 : 1
		211	44	92	28	47	3·5 : 1
Desi ♂ × Bhadya ♀	120	204	15	42	8	19	3·4 : 1
		206	17	24	3	15	3·0 : 1
		209	50	92	47	71	2·7 : 1
Desi ♂ × Bhadya ♀	125	213	15	20	10	10	4·5
		214	54	76	70	88	2·3 : 1
Total.			369	806	482	558	3·0 : 1

F_3 Generation.

No artificial self-fertilizations were made during 1910, but, at the end of the season, seed produced by natural fertilization was preserved from single plants of each type, in each of the plots mentioned in Tables I and II. In the present season, 1911, it was found impossible to sow the whole of the seed thus collected. Attention was therefore confined to the progeny of plants in the following plots, *viz.*:—Nos. 206, 209, 261, 262, and 263, our observations on which are contained in the following pages. The following diagram shews at a

glance the pedigree of the plants detailed in Tables III and IV :—

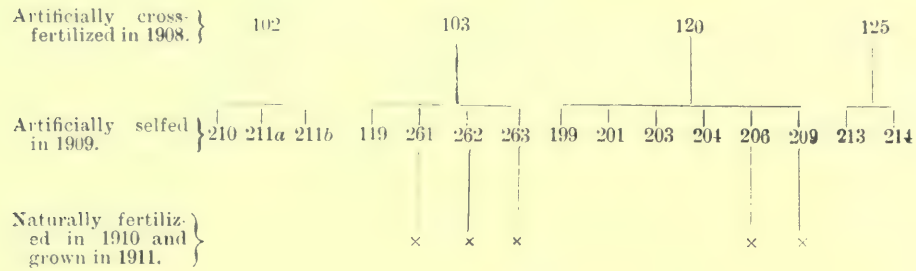

Artificially cross-fertilized in 1908.
102
103
120
125
Artificially selfed in 1909.
210 211a 211b 119 261 262 263 199 201 203 204 206 209 213 214
Naturally fertilized in 1910 and grown in 1911.
× × × × ×

Table III.

Descendants, in the F_3 generation, of plants, flowers of which were self-fertilized in the F_1 generation.

			Red.		Green.	Ratio of red to green.
Descendants of plan No. 206.	1,370	plants raised from a deep red plant R_1 were :—	1,018	:	352	2·9 : 1
	2,930	,, ,, ,, ,, R_2 ,,	2,127	:	807	2·7 : 1
	1,336	,, ,, pale ,, P_1 ,,	1,000	:	336	3·0 : 1
	1,268	,, ,, ,, ,, P_2 ,,	951		317	3·0 : 1
	1,371	plants raised from a plant with green stem and red petioles GR_1 were :—	1,038	:	333	3·1 : 1
	1,411	plants raised from a plant with green stem and red petioles GR_2 were :—	994	:	417	2·4 : 1
	2,406	plants raised from a pure green plant G_1 were :—	35	:	2,371	1·0 : 68
	2,401	,, ,, ,, ,, G_2 ,,	39	:	2,365	1·0 : 60
Descendants of 209.	801	plants raised from a deep red plant, R_1 were :—	632	:	179	3·5 : 1
	581	,, ,, ,, R_2 ,,	437	:	144	3·0 : 1
	1,210	,, ,, ,, R_3 ,,	894	:	316	2·8 : 1
	750	,, ,, ,, R_4 ,,	750	:	0	.....
	2,407	,, ,, pale red P_1 ,,	1,819	:	588	3·1 : 1
	90	,, ,, ,, P_2 ,,	90	:	0	.....
	257	,, ,, plant with green stems and red petioles and fruits GR_1 ,,	257	:	0	.....
	1,007	,, ,, ,, GR_2 ,,	733	:	274	2·7 : 1
	584	,, ,, ,, GR_3 ,,	435	:	149	3·0 : 1
	2,528	,, ,, green plant G_1 ,,	10	:	2,618	1 : 262
	1,588	,, ,, ,, G_2 ,,	30	:	1,558	1 : 52
	1,892	,, ,, ,, G_4 ,,	59	:	1,833	1 : 31

TABLE III.—(*contd.*)

Descendants, in the F_3 generation, of plants, flowers of which were self-fertilized in the F_1 generation.—contd.

					Red.		Green.	Ratio of red to green.
Descendants of 261.	1,562	plants raised from a pale red plant,	P_1	were :—	1,175	:	387	3·0 : 1
	1,363	,, ,, ,,	P_2	,,	1,020	:	343	3·0 : 1
	379	,, ,, a green stemmed plant having red petioles and fruits	GR_1	,,	379	:	0	
	805	,, ,, a green stemmed plant having red petioles and fruits	GR_2	,,	593	:	212	2·7 : 1
	1,054	,, ,, green	G_1	,,	17	:	1,037	1 : 61
	684	,, ,, ,,	G_2	,,	19	:	665	1 : 35
Descendants of 262.	1,322	plants raised from a deep red plant,	R_1	were :—	999	:	323	3·1 : 1
	1,734	,, ,, ,,	R_2	,,	1,313	:	421	3·1 : 1
	201	,, ,, ,,	R_3	,,	201	:	0	.....
	1,958	,, ,, light red	P_1	,,	1,469	:	489	3·0 : 1
	3,017	,, ,, ,,	P_2	,,	2,309	:	708	3·3 : 1
	1,892	,, ,, ,,	P_3	,,	1,423	:	469	3·0 : 1
	619	,, ,, green stemmed plant with red petioles	GR_1	,,	443	:	176	2·5 : 1
	1,205	,, ,,	GR_2	,,	911	:	294	3·1 : 1
	90	,, ,, ,,	GR_3	,,	90	:	0	..
	2,266	,, ,, green plant	G_1	,,	17	:	2,249	1 : 132
	3,777	,, ,, ,,	G_2	,,	61	:	3,716	1 : 61
Descendants of 263.	298	plants raised from a deep red plant,	R_2	were :—	298	:	0	.....
	1,431	,, ,, pale red	P_1	,,	1,054	:	377	2·8 : 1
	2,752	,, ,, ,,	P_2	,,	2,065	:	687	3·0 : 1
	3,368	,, ,, green stemmed plant with red petioles	GR_1	,,	2,628	:	740	3·6 : 1
	884	,, ,, ,,	GR_2	,,	659	:	225	2·9 : 1
	332	,, ,, green plant	G_1	,,	13	:	319	1 : 25
	991	,, ,, ,,	G_2	,,	27	:	964	1 : 36

In the following Tables, IV*a*, IV*b*, IV*c*, it can be seen at a glance that the different types of unfixed red plants of the F_2 generation behave similarly in producing progeny consisting of red plants and green ones approximately in the ratio of 3 : 1.

TABLE IV*a*.

Unfixed dark red plants yielded progeny as follows :—

Name of parent plant.	Number of red plants in progeny.	Number of green plants in progeny.
206.R_1	1,018	352
— R_2	2,127	803
209.R_1	632	179
— R_2	437	144
— R_3	894	316
262.R_1	999	323
— R_2	1,313	421
TOTALS ...	7,420	2,538

Mean ratio of red : green = 2·92 : 1.

TABLE IV*b*.

Unfixed light red plants yielded progeny as follows :—

Name of parent plant.	Number of red plants in progeny.	Number of green plants in progeny.
206.P_1	1,000	336
P_2	951	317
209.P_1	1,819	588
261.P_1	1,175	387
— P_2	1,020	343
262.P_1	1,469	489
P_2	2,309	708
— P_3	1,423	469
263.P_1	1,054	377
P_2	2,065	687
TOTALS	14,285	4,701

Mean ratio of red to green = 3·04 : 1.

Table IVc.

Unfixed plants, having green stems with red petioles and fruits yielded progeny as follows :—

Name of parent plant.	Number of red plants in progeny.	Number of green plants in progeny.
206.GR_1	1,088	333
— GR_2	994	417
209.GR_2	733	274
— GR_3	435	149
261.GR_2	593	212
263.GR_1	2,628	740
— GR_2	659	225
262.GR_1	433	176
— GR_2	911	294
Totals	8,424	2,820

Mean ratio of red to green = 2·99 : 1.

Another diagram will serve to make clear the origin of the next series of plants : descendants, in the F_2 generation, of plants, flowers of which were allowed to fertilize naturally in the F_1 generation (vide Table II). The reader will note that in 1909 their grandparents were naturally fertilized, and not artificially selfed as were those of the preceding series.

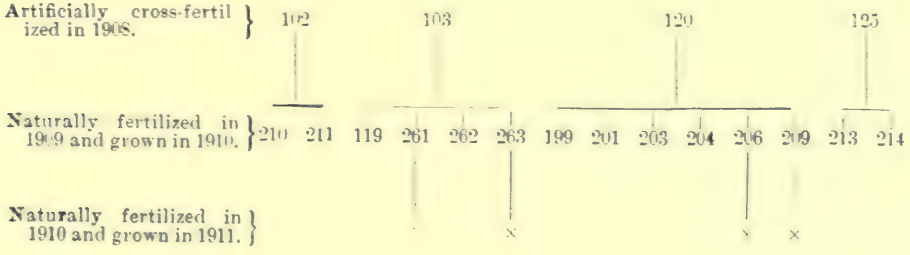

Artificially cross-fertilized in 1908.
102
103
120
125
Naturally fertilized in 1909 and grown in 1910.
210 211 119 261 262 263 199 201 203 204 206 209 213 214
Naturally fertilized in 1910 and grown in 1911.

Table V.

Descendants F_3 generation of the plants mentioned in Table II, and of which the pedigrees are given in the above diagram.

							Red.		Green.	Ratio.
Descendants of 206.	1,651	plants raised from a	deep red	plant	R_1	were :—	1,254	:	397	3·2 : 1
	1,926	,,	,,	,,	,, R_2	,,	1,419	:	507	2·8 : 1
	1,030	,,	,,	light red	,, P_1	,,	835	:	195	4·3 : 1
	1,600	,,	,,	,,	,, P_2	,,	1,600	:	0	——
	64	,,	,,	green	plant G_1	,,	1	:	63	1 : 63
	1,157	,,	,,	,,	,, G_2	,,	15	:	1,142	1 : 76
Descendants of 209.	1,025	plants raised from a	deep red	plant	R_1	,,	782	:	243	3·2 : 1
	801	,,	,,	,,	,, R_2	,,	801	:	0	——
	567	,,	,,	,,	,, R_3	,,	407	:	150	2·8 : 1
	1,389	,,	,,	light red	,, P_1	,,	1,389	:	0	——
	1,199	,,	,,	,,	,, P_2	,,	899	:	300	3·0 : 1
	904	,,	,,	,,	,, P_3	,,	904	:	0	——
	670	,,	,,	green	plant G_1	,,	2	:	668	1 : 334
	1,374	,,	,,	,,	,, G_2	,,	12	:	1,362	1 : 113
	1,379	,,	,,	,,	,, G_3	,,	10	:	1,369	1 : 137
Descendants of 261.	896	plants raised from a	deep red	plant	R_1	,,	662	:	234	2·8 : 1
	1,219	,,	,,	,,	,, R_2	,,	931	:	288	3·2 : 1
	1,090	,,	,,	light red	,, P_1	,,	792	:	298	2·7 : 1
	752	,,	,,	,,	,, P_2	,,	568	:	184	3·1 : 1
	1,105	,,	,,	green	,, G_1	,,	8	:	1,097	1 : 137
	1,247	,,	,,	,,	,, G_2	,,	14	:	1,233	1 : 88
Descendants of 263.	1,148	plants raised form a	deep red	plant	R_1	,,	865	:	283	3·1 : 1
	1,184	,,	,,	,,	,, R_2	,,	899	:	285	3·1 : 1
	1,098	,,	,,	light red	,, P_1	,,	1098	:	0	——
	1,088	,,	,,	,,	,, P_2	,,	830	:	258	3·2 : 1
	1,330	,,	,,	green	plant G_1	,,	27	:	1,303	1 : 49
	228	,,	,,	,,	,, G_2	,,	8	:	220	1 : 28

Table VI gives an analysis of the results for unfixed reds included in Table V.

TABLE VI*a*.

Unfixed dark red plants yielded progeny as follows :—

Name of parent.	No. of red plants in progeny.	No. of green plants in progeny.
206.R_1	1,254	397
— R_2	1,419	507
209.R_1	782	243
— R_3	417	150
261.R_1	662	234
— R_4	931	288
263.R_1	865	283
— R_2	899	285
TOTALS ...	7,229	2,387

Mean ratio of red to green = 3·03 : 1

TABLE VI*b*.

Unfixed light red plants yielded progeny as follows :—

206.P_1	835	195
209.P_2	899	300
261.P_1	792	298
— P_2	568	184
263.P_2	830	258
TOTALS ..	3,924	1,235

Mean ratio of red to green = 3·17 : 1.

Taking a grand total of all the progeny in the F_2 generation from unfixed red plants of the F_2 generation we get :—

Total of red plants in progeny.		Total of green plants in progeny.	Ratio of red to green.
Table IV*a*.	7,420	2,538	...
Table IV*b*.	14,285	4,701	.....
Table IV*c*.	8,424	2,820	...
Table VI*a*.	7,229	2,387	.....
Table VI*b*.	3,924	1,235	.....
GRAND TOTAL	41,282	13,681	3·02 : 1

Thus, in a total of 54,963 plants of the F_3 generation, produced from unfixed reds of the F_2 generation, the ratio of red plants to green ones is almost exactly as 3 : 1.

Fixed Red Plants.

In Tables III and V, it will be seen that a number of plots in the F_3 generation contained no green plants, *viz.* :—

209.R_1	Table III.	206.P_2	Table V.
— P_2		209.R_2	
—GR_1		— P_1	
261.GR_1		— P_3	
262.R_3		263.P_1	
—GR_3			
263.R_2			

In none of these plots is a single green plant to be found and the plants are therefore, presumably, fixed with reference to the inheritance of red colour. On the other hand, as regards degree of colouration ; while two or three plots contain practically only one type of red plant, the plants in the majority of these plots, as was the case with the red plants of the F_2 generation (Tables I and II), are a mixture of the several shades of red, enumerated at the commencement of this paper (p. 1, types *a*, *b*, *c*). Differences of such magnitude as these, if hereditary, have hitherto been held to constitute the distinction between one race and another.

In the following Table No. VII it will be seen that one of the plots (No. 263.R_2) contained practically only dark red plants, while in a second (No. 262.R_3) were 85 per cent. of dark red plants. In a third plot all the plants had green stems with red petioles and fruits. Thus, in the latter case, by crossing a pure green jute with a dark red one, it has been possible to produce, pure and fixed, a common intermediate colour type, an interesting fact which suggests that the origin of the other intermediate races of jute, at present under cultivation in Bengal, might also, possibly, be traced to hybridization.

An attempt has been made to count the representatives of each shade of red in the plots containing only red plants; but an accurate classification has been found almost impossible, owing to the number of colour gradations and the difficulty experienced in apportioning them under the right heads. The figures are probably therefore not very reliable on this account; but they are reproduced here for what they are worth.

Table VII.

Shewing the approximate number of plants of different shades of red in plots (F_3 generation) containing no pure green plants :—

Number of plot.	Number of Plants.		
	Dark red.	Light red.	Green stems with red petioles and fruits.
209.R_2	249	**473**	78
209.R_4	87	112	**233**
262.R_3	**173**	12	16
263.R_2	**293**	0	8
209.P_1	2	331	**1.078**
209.P_2	49	51	**84**
209.P_3	233	**715**	0
206.P_2	418	386	**1.259**
263.P_1	256	**446**	395
209.GR_1	0	157	**454**
261.GR_1	210	238	**468**
262.GR_3	0	0	**90**

Of these No. 262.GR_3 is a pure plot of green stemmed plants with red petioles and fruits. No. 263.R_2 is a practically

pure dark red plot and No. 9 contains about 85 per cent. of dark red plants. In the remainder there is no satisfactory approximation, either to one shade of red, or to a constant ratio between the different types. We hope to pursue this point further. In the present season (1911), the seed was sown rather too close together in the plots; so that it was found necessary to thin out a number of plants when they were about six weeks old. At this stage, while it is perfectly easy to distinguish between a pure green plant and one containing red colour, it is more difficult to say whether a red plant of a particular shade will retain its colour in unchanged intensity, throughout its growth. Of course, the thinning. just referred to, involved an immediate classification of the plants taken out, and it is just possible that an error has crept in here, as some of the plants counted at the time of thinning might have been apportioned differently at a later stage. Next season, arrangements will be made for the plants to be far enough apart in the plots to avoid the necessity for thinning.

In discussing the question of change of colour, it is worthy of note that exposure to sun-light appears to have a certain effect in deepening the red colour in a plant. For instance, the upper portions of a plant in the centre of a well-grown plot are the only ones which receive any large amount of direct sun-light. It is often seen that, under such conditions, the upper branches of a plant, which contains only a small amount of red colour, have a distinctly pink tinge; while its stem, in the shade, appears pure green. On the other hand, plants in the outside of the same plot often shew a trace of pink in their stems also.

Descendants, in the F_3 generation, of plants which were pure green in the F_2 generation.

Seed from the following plants produced a majority of green plants in the F_3 generation. The relative number of green and red plants given in Tables III and V are reproduced in Table VIII.

Table VIII.

Shewing the extent of impurity, consisting of red plants, in plots which should have been pure green.

	Name of Plants.	Number of red plants.	Number of green plants.	Ratio of red to green.
Table III.	206.G_1	35	2,371	1 : 68
Do.	—G_2	39	2,365	1 : 60
Do.	209.G_1	10	2,618	1 : 262
Do.	—G_3	30	1,558	1 : 52
Do.	—G_4	59	1,833	1 : 31
Do.	261.G_1	17	1,037	1 : 61
Do.	—G_2	19	665	1 : 35
Do.	263.G_1	13	319	1 : 25
Do.	—G_2	27	964	1 : 36
Do.	262.G_1	17	2,249	1 : 132
Do.	—G_2	61	3,716	1 : 61
Table V.	206.G_1	1	63	1 : 63
Do.	—G_2	15	1,142	1 : 76
Do.	209.G_1	2	668	1 : 334
Do.	—G_2	12	1,362	1 : 113
Do.	—G_3	10	1,369	1 : 137
Do.	261.G_1	8	1,097	1 : 137
Do.	—G_2	14	1,233	1 : 88
Do.	263.G_1	27	1,303	1 : 49
Do.	—G_2	8	220	1 : 28
	Totals	424	28,151	
	Mean ratio of red to green			1 : 66

This is equivalent to an amount of red impurity in the green plots averaging 1·5 per cent.

In the F_2 generation the green plants were surrounded by pure and impure reds in the ratio of 3 : 1. The pure reds, the number of which was presumably equal to about half that of the impure ones, would, on crossing with the green plants, produce only

red progeny: similarly, the impure reds would produce red and green progeny in equal numbers. It may therefore be assumed, that the 1·5 per cent. of red plants found in the green plots, represents about $\frac{2}{3}$ of the total amount of impurity which would actually have been produced, if all the red plants had been pure. In the latter case, the amount of impurity found might be rather more than 2 per cent. Arguing on this basis, it follows that, under the most favourable circumstances for cross-fertilization, jute would tend to breed true to the extent of about 98 per cent. As a matter of fact, our experience in growing pure single plant cultures of different colours, in adjacent blocks, leads us to believe that the amount of crossing which takes place, under ordinary conditions, between neighbouring fields for instance, is probably much less than 2 per cent. In 1909, fifty single plants of several different colour types were selected. In 1910, the seed from each plant, sown separately in adjacent plots, reproduced the parent type absolutely true in every case. Thirty-five out of forty-seven of these plots contained only pure red plants, the remainder being pure green. Immediately adjacent were plots of the F_2 generation of hybrids already described in this paper. Thus, in the presence of abundance of insects at the time of flowering,* there was no lack of facilities for chance crossing between plants in the green plots and those in the surrounding red ones; and the percentage of red plants, in the progeny raised from the seed of the green plots, should therefore be an index of the extent to which chance crossing takes place under these circumstances.

In the present season 1911, seed from these green plots has been sown in $\frac{1}{100}$th acre plots and the number of red plants found in the latter has been counted. The results of the counts, together with the corresponding percentages of red impurity, are given in Table IX. The average number of plants in a $\frac{1}{100}$th acre plot may be taken as about 1,500.

* Both at Pusa and Dacca, insects, particularly *Apis florea, Linn.*, are abundant visitors to the flowers of *Corchorus capsularis*.

TABLE No. IX.

No. of plot.	No. of red plants found.	Percentage of impurity.
12.b	0	0
19.b	2	0·15
27	2	0·13
49	1	0·07
55	40	2·50
57	4	0·25
58	0	0·0
59	1	0·07
60	2	0·13
65	3	0·2
66	0	0·0

Even these figures probably give an exaggerated idea of the amount of crossing which takes place between one field of jute and another. The excessive number of red plants in plot 55 is probably due to accidental contamination of the seed before sowing.

CONCLUSIONS.

From the data in this paper we conclude that :—

(1). When a pure green jute, *i.e.*, one containing no red colour, is crossed with a fixed red plant, or *vice versâ*, Mendel's law is obeyed, the red acting as a simple dominant.

(2). The F_1 generation of hybrids appears to consist entirely of plants of one tint of redness, which, it should be noted, is less dense than the colour of the red parent. The red plants of the F_2 generation, on the other hand, vary widely in the amount of red colour they contain. Moreover, seed from red plants of the F_2 generation has produced progeny of the F_3 generation which, though apparently quite fixed as regards possession of red colour, shews, in most cases, the same variation between individuals in regard to the intensity of red colouring, as characterized the red plants of the F_2 generation.

(3). The facts (*a*), that one result of these experiments has been to produce examples, fixed or unfixed, of all the intermediate colour types of jute hitherto met with, including a pure fixed culture of one of the commonest of these : (*b*) that

we have shewn a small amount of chance crossing to be possible, are reasonable evidence in favour of tracing, to chance hybridization, the origin of the intermediate coloured races of jute in common cultivation.

(4). Self-fertilization is, nevertheless, the rule in the species; and, while chance crossing probably does take place to a small extent, it is not likely to exceed 2 per cent. (*i.e.*, about 98 per cent. of the plants would tend to breed true), under the most favourable conditions for the production of cross-bred plants. Indeed, there is evidence to shew that, in ordinary circumstances, the amount of chance crossing may not be much greater than 0·2 per cent.

(5). It would appear therefore that, in carrying out breeding experiments with jute, there is little need for elaborate precaution to prevent cross-pollination; and that no more than ordinary care would be necessary to preserve a superior race of jute from contamination by adjacent inferior crops.

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